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A UNIQUE CASE OF BILATERAL HECTOCOTYLIZATION IN THE NORTH PACIFIC GIANT OCTOPUS (*ENTEROCTOPUS DOFLEINI*)

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INTRODUCTION

Life-history information regarding most cephalopod species is somewhat scarce, and information relating anatomical anomalies of cephalopods is even more limited. For octopus species, the few anomalies that have been reported include: arm bifurcations (Smith, 1907; Okada, 1965; Gonzalez & Guerra, 2006), fourth-arm hectocotylus (Robson, 1929), hexapody (Toll & Binger, 1991), septapody (Gleadall, 1989), decapody (Toll & Binger, 1991), and double hectocotylization (Robson, 1929; Palacio, 1973).

Most male octopus have a modified third right arm or hectocotylus that is specialized for passing sperm packets to females. The tip of this specialized arm, known as a ligula, is spoon-shaped bearing a seminal groove ending in a rounded calamus. There are only three species of octopus that typically have the hectocotylized arm on the third left arm instead of the third right: *Scaeurgus unicirrhus*, *Euaxoctopus panamensis* and *Pteroctopus tetracirrhus* (Palacio, 1973).

In over one hundred years of research, double hectocotylization has been reported in only six individual cases in six different species of octopus including: *Eledone cirrhosa* (by Appellöf, 1892), *Octopus briareus* (by Robson, 1929), *Octopus vulgaris* (by Palacio, 1973), *Octopus selene* (by Palacio, 1973), *Octopus chierchiae* (by Roy Caldwell, personal communication) and *Octopus minor* (by Higashide et al., 2007). In each case, the third right arm was hectocotylized, along with an additional arm from the right side of the body (unilateral hectocotylization) or a left arm (bilateral hectocotylization).

This paper presents not only the first documentation of double hectocotylization for the North Pacific giant octopus (*Enteroctopus dofleini* Wülker, 1910), but also the first case of any cephalopod having double hectocotylization not including either the third right or left arm.

METHODS

Over a period of two years, approximately 5,000 male *E. dofleini* were observed in field studies performed at the edge of the Bering Sea shelf, 20 km north and east of Unalaska Island, Alaska (54°04'N, 166°25'W, Fig. 1). In September 2011, a male *E. dofleini* with bilateral hectocotylization was captured in a standard 2.5 m by 2.5 m groundfish pot, frozen and transported to a laboratory in Unalaska for future analysis and description. In October 2011, the octopus was defrosted and examined. The total weight was measured to the nearest 0.1 kilogram, gonad and stomach were weighed to the nearest gram and spermatophores were counted. Each of the arms was measured to the nearest centimeter and the number of suckers was counted. For the two hectocotylized arms, ligula length was measured in centimeters and evaluated as a percentage of the total length of the hectocotylized arm. The external and internal anatomical measurements of this individual were compared to other male *E. dofleini* of approximately the same total weight (n = 21 and n = 10 respectively).

RESULTS

This specimen (UAM Inv 8145), henceforth referenced as R4L4, was morphologically identical to other males of this size class except for the double hectocotylization of the fourth right and left arms (Fig. 2). This octopus weighed a total of 14.1 kg with a stomach weight of 100 g. The gonad weight for R4L4 was 896 g, and no spermatophores were visible upon inspection. The reproductive tract showed the octopus was immature, but developing normally. Both the gonad weight and the maturity status of the individual were considered normal when compared to similarly sized *E. dofleini*. The mean standard arm length, not including hectocotylized arms

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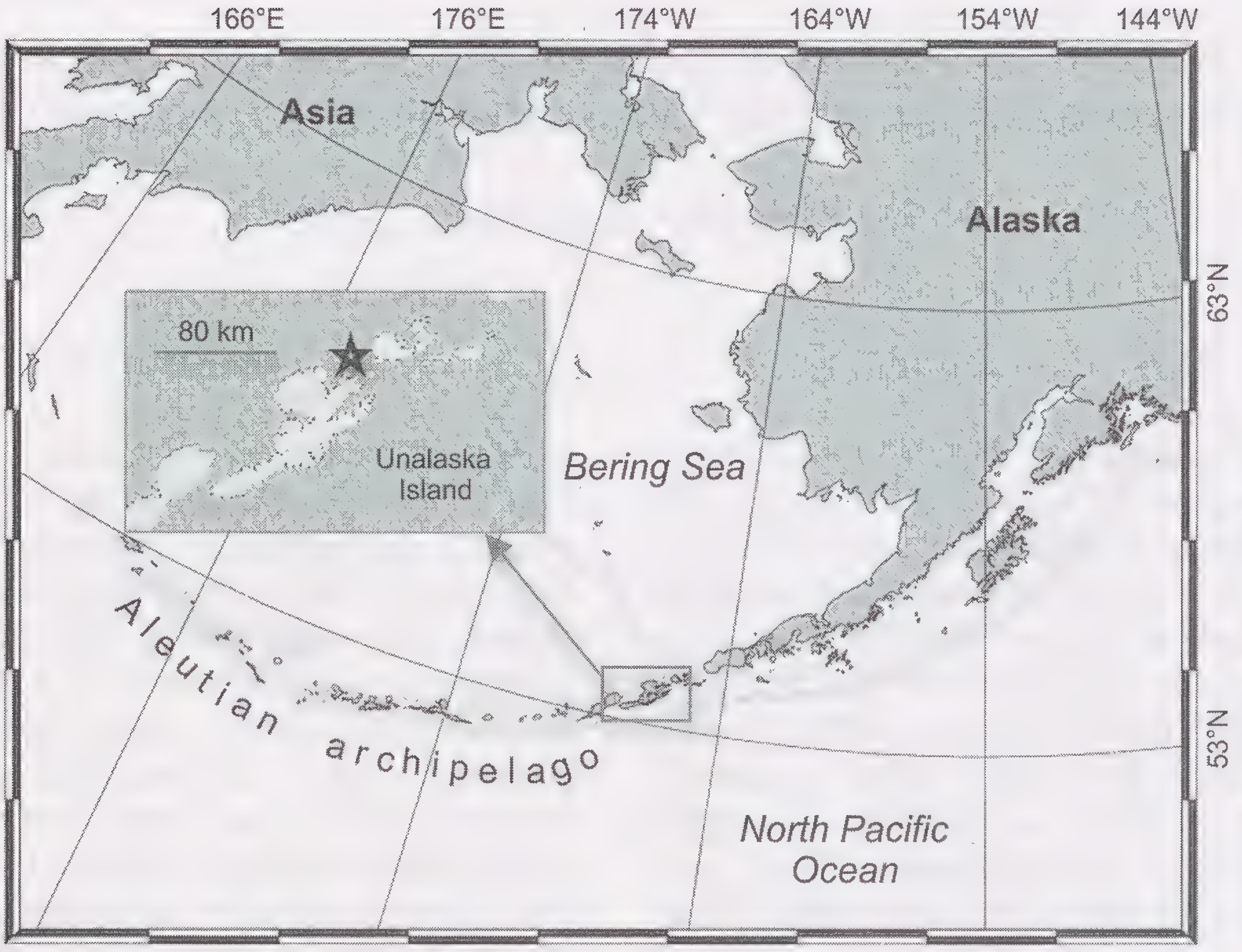

FIG. 1. Capture location (star) of the double hectocotylized *E. dofleini*.

and one arm missing a tip, was 136 ± 0.9 SE cm and the number of suckers per arm was 230 ± 9 SE (Table 1). The length of the fourth right hectocotylized arm, henceforth referenced as R4, was 121 cm and the length of the fourth left hectocotylized arm, henceforth referenced as L4, was 124 cm. The ligula of R4 (29 cm) was 24% of the hectocotylized arm while the ligula of L4 (25 cm) was 20% of the hectocotylized arm.

DISCUSSION

Reports of double hectocotylization and abnormally hectocotylized arms in cephalopods are extremely rare. For all octopus species, only six cases of double hectocotylization and one case of fourth-arm hectocotylization have been reported (Massy, 1930). Anecdotal reports corroborate this reported rarity as thousands of individuals have been examined by scientists for similar arm anomalies, and negative reports were received for *Octopus maya* and *Octopus vulgaris* in Yucatan, Mexico (Miguel Cabrera, personal communication), *Octopus mimus* in Lima, Peru (Franz Cardoso, personal communication), and *Enteroctopus dofleini* in Canada and Alaska (David Scheel & Jim Cosgrove, personal communication). As such, this individual is unique as both the first documented case of double hectocotylization for this species and for any species of cephalopod that did not include a typical hectocotylized third arm.

Unlike previous cases of reported double hectocotylization, both hectocotylized arms of R4L4 were approximately equal in total length, ligula

TABLE 1. Comparison of arm length, suckers and ligula length for each of the arms of R4L4 (R1 = first right, R2 = second right, etc.).

	R1	R2*	R3	R4 (hecto)	L1	L2	L3	L4 (hecto)
Arm length (cm)	133	99	136	121	137	135	138	124
Suckers	232	94	201	94	220	248	251	104
Ligula length (cm)				29				25

*missing last few cm of arm

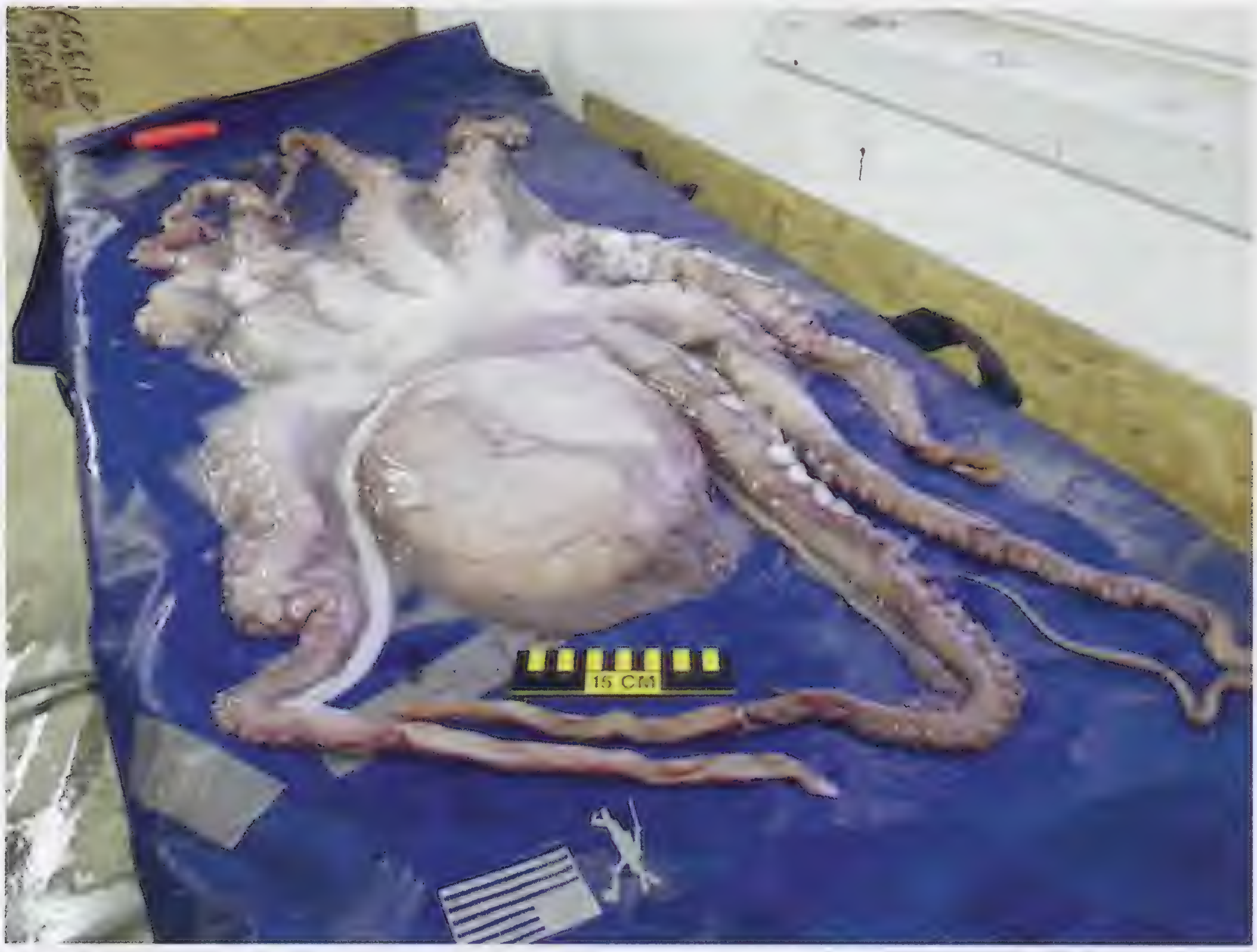

FIG. 2. Bilateral hectocotylization in *E. dofleini* on the fourth right and fourth left arms.

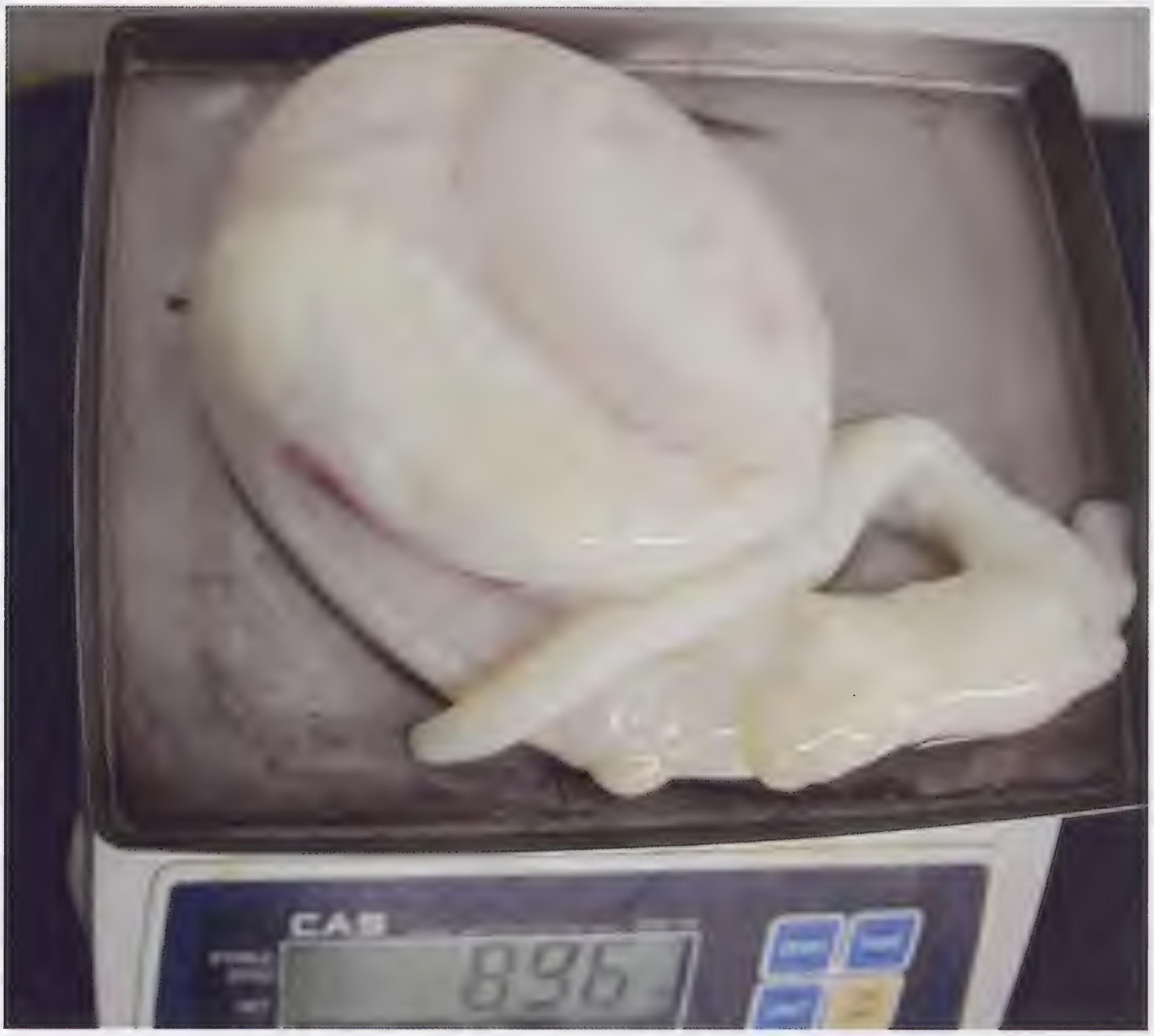

FIG. 3. Reproductive organs of R4L4. White band on the left side is a developing spermatophore.

TABLE 2. Comparison of external attributes of R4L4 to means of similarly sized conspecifics*. Arm length and number of suckers for R4L4 was calculated using only intact standard arms.

	Arm length (cm) ± SE	Number of suckers ± SE	Total weight (kg) ± SE	Gonad weight (g) ± SE	Stomach weight (g) ± SE	Number of spermatophores ± SE
R4L4	135 ± 1	230 ± 9	14.1	896	100	0
*E. dofleini**	139 ± 1	245 ± 8	14.1 ± 0.1	932 ± 37	304 ± 48	4.0 ± 1.3

*13 το 15 kg in total weight (n = 21)

length, and number of suckers (Table 1). This contrasts with a previous report in which third right hectocotylized arms were shorter in total length, had more rows of suckers, and had a larger ligula than supernumerary hectocotylized arms (Palacio, 1973). As compared to other cases of double hectocotylization, the close similarity in the two hectocotylized arms of R4L4 suggests that anatomical anomalies may not be expressed similarly across all species or individuals.

Similarities in gonadal development and ligula length suggest that R4L4 was at a similar reproductive state and was equally successful in foraging for prey when compared to similar sized conspecifics. Though individual measurements of testes, vas deferens, seminal vesicle, prostate, Needham's sac and genital bag were not taken, it appeared that spermatozoa were being processed into spermatophores in the seminal vesicle which was a sign of a maturing individual (Fig. 3). Though R4L4 did not have any fully formed spermatophores present, three of ten other *E. dofleini* examined also did not have spermatophores, suggesting that this level of reproductive maturity is within the normal range for similarly sized conspecific males. Furthermore, the standard arm length and number of suckers of R4L4 was similar to the other males, suggesting that double hectocotylization did not hinder the growth or number of suckers on typical arms (Table 2).

This is the first account of double hectocotylization for *E. dofleini* and double hectocotylization not involving the typical third right or left arm in any cephalopod species. It is possible that arm anomalies such as this are a regular occurrence, but due to a scarcity of research effort in many species, this is the first time this type of anomaly has been documented.

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